Section 936
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MICROWAVE/MULTIPLEX WIRE LINE ENTRANCE LINKS

CONTENTS

1. GENERAL

1.1 This Section is to provide REA borrowers, consulting engineers and other interested parties with technical information for use in the design and construction of wire line entrance links (WLEL's) for microwave/multiplex systems.

1.2 When a microwave radio terminal is located some distance from its associated multiplex terminal, a wire line entrance link is required to interconnect them. Distances may be several hundred feet to several miles. Repeaters are used to extend this distance. Repeatered systems require repeater power feed circuitry and are essentially the same as wideband coaxial cable systems. Figure 1 is a simplified block diagram of a typical wire line entrance link consisting of central office equipment and outside plant equipment. (The outside plant equipment is not required in a WLEL located entirely within a single building.)

2. TERMINAL EQUIPMENT

2.1 Wire line entrance link terminal equipment connects the line facility with the radio or multiplex terminal. WLEL terminals contain jacks to patch and test, lightning surge protection, amplifiers to overcome the line loss, equalizers to compensate for differences in line attenuation at different frequencies, regulation and, in some applications, emphasis networks to optimize the radio performance.

2.2 Radio and multiplex terminals have 75 ohm coaxial line connections designed to connect to the WLEL terminal via a flexible 75 ohm coaxial cable. Some terminal equipment has 124 ohm balanced connections. This matches the impedance of video cable.

2.3 The line facility side of the WLEL terminal is designed to interconnect with balanced or unbalanced line facilities. Again, 75 ohms is the unbalanced impedance and 124 ohms is the balanced impedance value. Other impedances are available on some equipment. The line side of the WLEL terminal is terminated in a line terminating panel.

2.4 Jacks for testing and patching are usually provided on the WLEL terminal. Coaxial or video connectors are provided on the line facility terminating panel.

2.5 Lightning surge protection is included in most WLEL terminal shelves. Protection may also be provided by adding a gas tube protector panel adjacent to the line terminating panel. If the gas tube panel can reduce the surge potential to an acceptable value (say 350V peak), the protection circuitry included in the WLEL terminal must further dissipate the surge to acceptable levels before it reaches sensitive electronic equipment.

2.6 Amplification becomes necessary when line losses attenuate the signal to a level which is below the acceptable receive level of the radio terminal or the multiplex terminal. Amplifiers are located in the WLEL terminal shelf.

2.7 Equalizers are needed to provide unequal attenuation in the inverse order of the way signal frequencies are attenuated in the line facility. An equalizer should cause enough loss at low frequencies to make their signal power equal to the signal power of the high frequency signals entering a line amplifier or repeater.

2.8 Pre-emphasis and de-emphasis networks may be a part of the WLEL terminal. When a pre-emphasis network is inserted ahead of a transmitter input, the wideband signal is attenuated in a specific pattern which causes greater transmitter frequency deviation at higher frequencies. A de-emphasis network must be placed in the receiver output to restore the original character of the transmitted miltiplex signal. When pre-emphasis and de-emphasis are matched to the radio transmitter and receiver characteristics, the radio equipment will contribute a fairly equal amount of noise at all multiplex frequencies.

2.9 Baseband regulators or regulating repeaters are needed where temperature changes would cause line signal level changes that exceed the system design objectives.

3. LINE FACILITIES

3.1 Line facilities for wire line entrance links are usually video or coaxial cables. Paired cables are used occasionally where only a narrow bandwidth is to be transmitted.

3.2 Video cable consists of a heavy gauge balanced pair of wires with a shield surrounding the pair (see Figure 2). This type of cable has excellent noise rejection in the presence of induced noise voltages. At the lowest multiplex frequencies (12 kHz) this is a real advantage. It means any portion of a frequency division multiplex spectrum may be transmitted over this type of facility. Video cables are manufactured in a variety of configurations. A single video pair can be obtained in a flexible assembly for indoor use. It is made of 19, 22 or 24 gauge wire, a double braided shield and jacketed with plastic. This type is used to interconnect the electronic equipment and the point where the line facilities are terminated. A single video pair may be obtained for outside aerial or buried applications. This type has a 16 gauge pair, double solid copper tape shields, an insulating wrap, a semiflexible outer metal shield and a thick plastic jacket. When service channel and alarm pairs are to be extended over the wire line entrance link, video cable may be obtained with several pairs of 19 or 22 gauge wire in a "composite" configuration. Composite cables are available with various numbers of video and small gauge pairs in a single sheath (see Figure 2). The video pairs in the outside plant facilities are usually terminated at a convenient point and spliced to a stub cable on the video terminating assembly. The video cable terminal may be located in the same equipment rack as the WLEL terminal (see Figure 3). Gas tube protectors may also be mounted in this equipment rack when they are needed. The flexible video cable should be connected in parallel with the protector circuitry.

3.3 A coaxial cable contains a heavy gauge center conductor surrounded by a metal shield which is also used as one of the signal conductors. This type of cable is susceptible to induced noise voltages at frequencies below about 100 kHz. As the signal frequency increases, more signal energy is concentrated near the inner surface of the outer conductor. This property makes the outer conductor serve as a satisfactory shield against unwanted frequencies while also performing as a conductor of the wanted signal. Of course, the inner conductor is subject to similar properties. In this case, the outer surface of the inner conductor becomes the signal carrying path. Coaxial cables, like video cables, are available in single coaxial or composite coaxial configurations (see Figure 2). Coaxial tubes for telephone systems are available in .174" and .375" diameters. The smaller diameter (.174") cable may be a good economic choice for some coaxial WLEL applications.

3.4 Figure 4 illustrates a terminating plan for a composite coaxial cable. A composite cable is chosen for the illustration because a typical WLEL will most likely contain two or more coaxial tubes and several 19 or 22 gauge pairs. The physical pairs are terminated in a terminal housing or on the MDF. The coaxial tubes are terminated in a cable terminal mounted in an equipment rack with the WLEL terminal.

4. APPLICATIONS

4.01 Applications of WLEL's are most satisfactory when the following effects are considered: (a) attenuation, (b) slope, (c) temperature, (d) frequencies, (e) noise levels, (f) signal levels, (g) channel loading, (h) reliability, and (i) protection.

4.02 Distances over which WLEL's may carry wideband signals depend on the type of line facilities, the number of message circuits to be carried and the performance objectives to be realized. Examples of applications using video and coaxial cable are included in Figures 5 and 6. In a real situation the real values for each variable must be used instead of those given in Figures 5 and 6. (An examination of these examples may raise questions which the following information proposes to answer.) Repeaters could, of course, extend distance limits of each type of WLEL.

4.03 Radio and multiplex equipments each have a range of line signal levels on which their design performance is based. Signals attenuated in the various WLEL terminal and line facilities may require additional amplification. Cable facilities represent the largest single attenuation factor. Frequency and attenuation are given in Figure 7 for a typical .375" coaxial cable. Figure 8 shows the same information for a typical 16 gauge video cable. Video cable is approximately twice as lossy as .375" coaxial cable. Attenuation in each type of cable increases as the signal frequency increases, but this relationship is not linear. Cable attenuation increases exponentially with increasing frequency. For frequencies used in WLEL's, an equation which adequately expresses this relationship is:

$$\alpha = \sqrt{f}\ c$$

In this equation, attenuation (α) is expressed in decibels per unit length of cable. Frequency (f) is expressed in megahertz. The constant (c) is a number derived from the physical dimensions and temperature of each type of cable. In Figure 8 the constant (c) is 9 when the cable is at a temperature of 68°F.

4.04 The increase of attenuation with increased signal frequency in a cable is called "slope." Slope may be offset by an equalizer which introduces less attenuation at higher frequencies. Most equalizers are passive devices. Active equalizers could be used to equalize levels over a range of cable temperatures. By careful design it is possible to equalize the effects of line attenuation so that all signal frequencies applied to an amplifier are very close to the same level. Some undesirable effects are present when equalization is not used. They are:

4.041 Signals applied to an FM radio transmitter at unequal levels cause its deviation to be different for each signal level. The signal to noise ratio worsens as the frequency deviation of an FM transmitter is reduced.

4.042 Wire line entrance link amplifiers designed to amplify all input frequencies by a fixed amount will have the effect of simultaneously amplifying some frequencies too much and others too little. If the amplifier is not designed to accept a wide range of input levels, the high level signal frequencies could overload it and the low level signals could be too close to the amplifier noise threshold.

4.043 Multiplex baseband input amplifiers could exhibit the same effects as described in 4.042.

4.044 Unequal levels passing through the multiplex supergroup and group demodulating amplifiers would make these amplifier gain adjustments confusing. This can add noise in the derived voice channels for reasons given in 4.042.

4.05 "Delay" is a word used to describe the time interval needed to transmit a single frequency signal through a transmission medium. This time interval may be expressed more precisely as "absolute delay." Just as there are differences in attenuation with frequency changes, so too are there differences in delay as different frequencies pass through the same medium. Delay equalizers are available to equalize the delays across a given bandwidth. However, it is less important to provide delay equalization in a wire line entrance link when it is to carry voice circuits than when it must carry a television signal. Voice channels do not lose intelligibility when a small amount of baseband delay distortion is present, whereas a television signal will have reflections or "ghosts."

07 Signal frequencies transmitted over wire line entrance links are mostly baseband spectrum frequencies. That is, 12 kHz to about 4 MHz for message service using frequency division multiplex terminals. elevision signal baseband spectrum is 10 Hz to around 10 MHz. Entrance ks used for message service require two video pairs or two coaxial es (one for each direction of transmission). Television service is en transmitted in one direction. Therefore, a WLEL used for a teleion distribution link would only require one video pair or one coaxial e to carry the signal in the wanted direction of transmission.

)8 Loading is important because all amplifiers are designed to carry a nominal signal not to be exceeded by a predetermined peak signal ve nominal. When the design load is exceeded, distortion will rise all channels. The power in 600 voice channels can be closely simulated applying an RMS power that is 12 dB higher than the single channel 3m RMS test tone power. If an amplifier designed for 600 channels ised in a system whose channel density is 300, the amplifier output be raised to take advantage of the reduced loading. Theoretically, nay be raised 3 dB. Considering the significance of loading, it is efore of great importance to select terminal equipment designed to y at least the initial traffic. It is prudent to select equipment can carry 2 to 10 times the initial traffic load. Traffic will be xture of voice and data signals. Data may be treated the same as e traffic when it is applied to the system at the same levels as voice signals (usually -16 dBm/channel). (Please refer to paragraph of TE&CM 934 for more complete information about loading.)

4.10 Amplitude equalization and its effects were discussed earlier. It should be sufficient to state that the difference in attenuation between the lowest and the highest frequency to be carried on the WLEL will be the total slope correction needed. Equalizers should be selected to complement this slope. An alternate way of selecting a quantity of slope equalization is to choose an equalizer that is designed to equalize specific increments of line length. For example, a one mile length of 16 gauge video cable would require that the application engineer first select an equalizer designed for a 16 gauge video pair. Then, he would designate that it be connected in a way which would make the sum of its line length increments close to 5280'. In this type of equalizer the smallest available line length increment might be 50 feet for 16 gauge video pairs and 100 feet for .375" coaxial cables.

4.11 Delay equalizers are available for baseband wire line entrance links using video pairs. This type of line facility introduces envelope delay differences measured in nanoseconds. When the WLEL is to be used for video transmission, it is desirable to add delay equalization.

4.12 Emphasis networks may be inserted just ahead of the radio transmitter input (pre-emphasis) and immediately after the receiver output (de-emphasis) to optimize the microwave link noise performance across the baseband. Most microwave radio manufacturers mount these networks in the radio bays. The networks are considered to be a part of the radio link. However, at least one manufacturer offers pre- and de-emphasis networks as a part of its wire line entrance link terminal equipment. This is a desirable arrangement when the microwave systems must be used alternately for video and message service. Separate preconditioned wire line entrance links can be terminated in a switch or patch bay where they can be switched into any one of several microwave systems.

4.13 Near end crosstalk (NEXT) is an undesirable effect resulting from reduced coupling loss between two or more signal transmission paths in a communications system. This effect may be measured as a quantity of noise. If it originates in the transmit portion of the system in which it is received, it could be detected as sidetone. If it originates in adjacent systems, it may or may not be intelligible. In any form it is undesirable and, therefore, the application engineer must be constantly aware of places where it can occur and where its effect can degrade system performance. High level transmit signals in the vicinity of low level receive signals are always suspect places to begin evaluating NEXT. A WLEL terminal is a good example. There is a possibility of -13 dBm transmit signals being in close proximity to -54 dBm receive signals. It is necessary then to maintain a large amount of coupling loss between these signals. If 70 dB of S/N ratio is to be maintained, it means that the unwanted signal must be 70 dB below -54 dBm or -124 dBm. Since the unwanted signal source is at a

-13 dBm level, it must be isolated from the received signal by the difference between -13 dBm and -124 dBm. This amounts to 111 dB of coupling loss that must exist if the desired S/N ratio is to be maintained. Equipment shelf wiring, office cabling and outside plant cable must be considered as sources of unacceptable coupling losses. The application engineer has little control over WLEL equipment shelf wiring but he does have control over levels, office cabling and outside plant cabling. As an example, Figure 6, item 18, shows a transmit level of -13 dBm. The received signal level is figured to be -46.1 dBm. Composite coaxial cable data shows NEXT values greater than 110 dB above 60 kHz. At 110 dB below the -13 value, an unwanted signal will be present at the same point as the -46.1 dBm signal. The S/N ratio in this case is 76.9 dB thus the 70 dB objective is met. Terminal equipment specifications should be examined to learn whether the proposed system levels will introduce unacceptable crosstalk. This information is not always given in a manufacturer's technical summary for its terminal equipment.

4.14 Factors which influence the reliability of wire line entrance links are no different than other equipment in a system. While it is true that equipment reliability is important, it is also true that this is only one of the important factors. The others are (1) the quality of application engineering, (2) the operating environment, (3) maintenance personnel, (4) spares and test equipment, (5) documentation, and (6) maintenance schedules. Most of these factors are at least partly under the control of the application engineer. Maintenance personnel and maintenance schedules are not. If the engineer will specify redundant active modules (amplifiers), the system reliability is increased. If spare video or coaxial lines are specified and terminated in convenient patching facilities, restoral time can be minimized when working lines fail. An alarm system which senses loss of a pilot tone is a quick way to alert personnel when a failure or level change has occurred. Engineers should aquaint themselves with the environment in which the equipment will work. When equipment performance specifications require controlled temperature, humidity and voltage sources, the engineer should specify environment conditioning equipment to assure that these controls are provided. An application engineer should arrange to provide drawings and maintenance manuals which will be needed to quickly locate a trouble. Spare modules can reduce the time to restore service. Adequate test equipment used by well trained personnel can aid restoration of service and help maintain system operation at peak performance. Application engineers should specify the levels of training needed to maintain the new equipment. Two well trained employees with good maintenance scheduling can maintain a vast amount of equipment provided the application engineer has done his work well. The net effect will be a reliable system.

4.15 Alarms and a service channel or order wire may be extended from the radio site to the distant end of the wire line entrance link. The application engineer may treat the wire line entrance link as if it were one-half of a radio repeater configuration. When this is done, the wideband cable facility carries all signals. High pass-low pass filters are inserted into the baseband to provide alarm and service channel access at the radio site. At the multiplex site, the engineer will treat the signals as if they were being derived from a radio terminal. An alternate method of extending the alarms and service channel is to utilize 19 or 22 gauge pairs included in a composite cable placed between the radio and multiplex sites. In this type of application the radio site is treated as a terminal with respect to the location of alarm and service channel filters. These signals are extended over the 19 or 22 gauge pairs to the multiplex site. Voice frequency gain devices may be required to adapt the signal levels to the end equipments. Attenuation of voice frequencies in video and coaxial cables is small compared to 19 or 22 gauge pairs. This can be seen by examining Figures 7 and 8 and comparing them with paired cable attenuation curves. Alarm systems most often use frequencies which are in the baseband range above the service channel (approximately 4 kHz) and below the lowest multiplex channel (approximately 12 kHz). Equipment and line losses must be examined carefully in this frequency spectrum. Selection of frequencies which are close to the band edge of filters should be avoided unless the "skirt" characteristics of filters are known. Experience has shown that application engineers devote an inordinate amount of engineering time to special alarm and service channel arrangements. Less cost and better performance can be had by accepting as much standard wiring as is reasonable to accomplish necessary functions.

5. COSTS

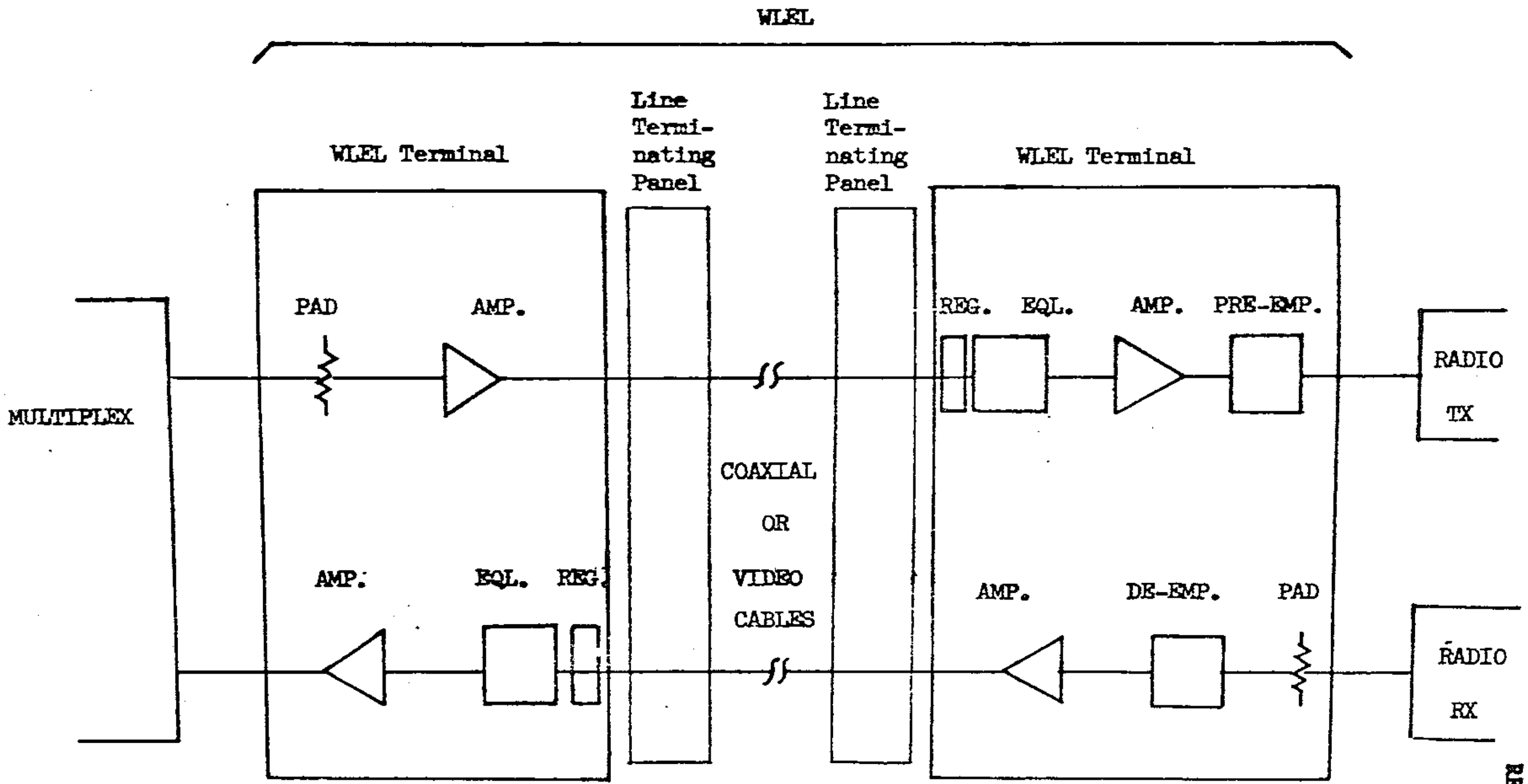
5.1 Costs given in this paragraph may be used as guides to make a cost comparison between the alternatives of installing a wire line entrance link or another link of microwave radio. These costs are approximate and reasonable as of the date of this TE&CM issue.

5.2 Costs of line facilities are divided between material costs and placement costs. Costs of terminal equipment are treated the same way.

5.3 Line materials will, of course, include the cable and its associated pole line hardware or buried plant hardware. Examples of cable costs are $1,500/1000 feet for composite cables consisting of four .375" coaxials with six 19 gauge pairs or four 16 gauge video pairs and six 19 gauge pairs. These are direct burial types. Aerial cables of the same numbers of pairs cost about $1,300/1000 feet. Pole line hardware cost is about $15/pole and the spacing is approximately 200 feet. An additional $1,000/terminal should be

allowed for mechanically terminating the outside plant cable in a suitable terminating assembly at each equipment location. Labor cost to place a pole is slightly less than the cost of each pole. Aerial cable placement cost is about 10 cents/foot. Labor cost for direct burial is about 5 cents/foot. Labor is costing about 35 cents/ foot for underground placement. Labor costs will vary considerably depending on terrain, size of project and cable sizes.

5.4 Costs of terminal equipment depend on the application. When maximum amplification, equalization and regulation are required, it is obvious that the cost will be much greater than a short WLEL requiring minimum or no amplification, etc. Since equipment manufacturers offer their equipment in a versatile arrangement, it is useful to itemize typical costs for each piece of terminal equipment. After studying various manufacturers' list prices, it appears that \$300 is a typical figure for an equipment shelf. The same price applies to each amplifier and each equalizer. High frequency patch jack assemblies will also cost about \$300 per terminal. Special regulated power supplies or converters can be estimated at \$300 per unit. A baseband regulator unit costs about \$3,000 for each direction of transmission. Continuity alarms cost about \$200 per terminal. Installation costs are estimated to be 15 percent of the terminal equipment cost.



NOTE: Line terminating panels are only necessary when the line is aerial or buried cable.

SIMPLIFIED BLOCK DIAGRAM

WIRE LINE ENTRANCE LINK

FIGURE 1

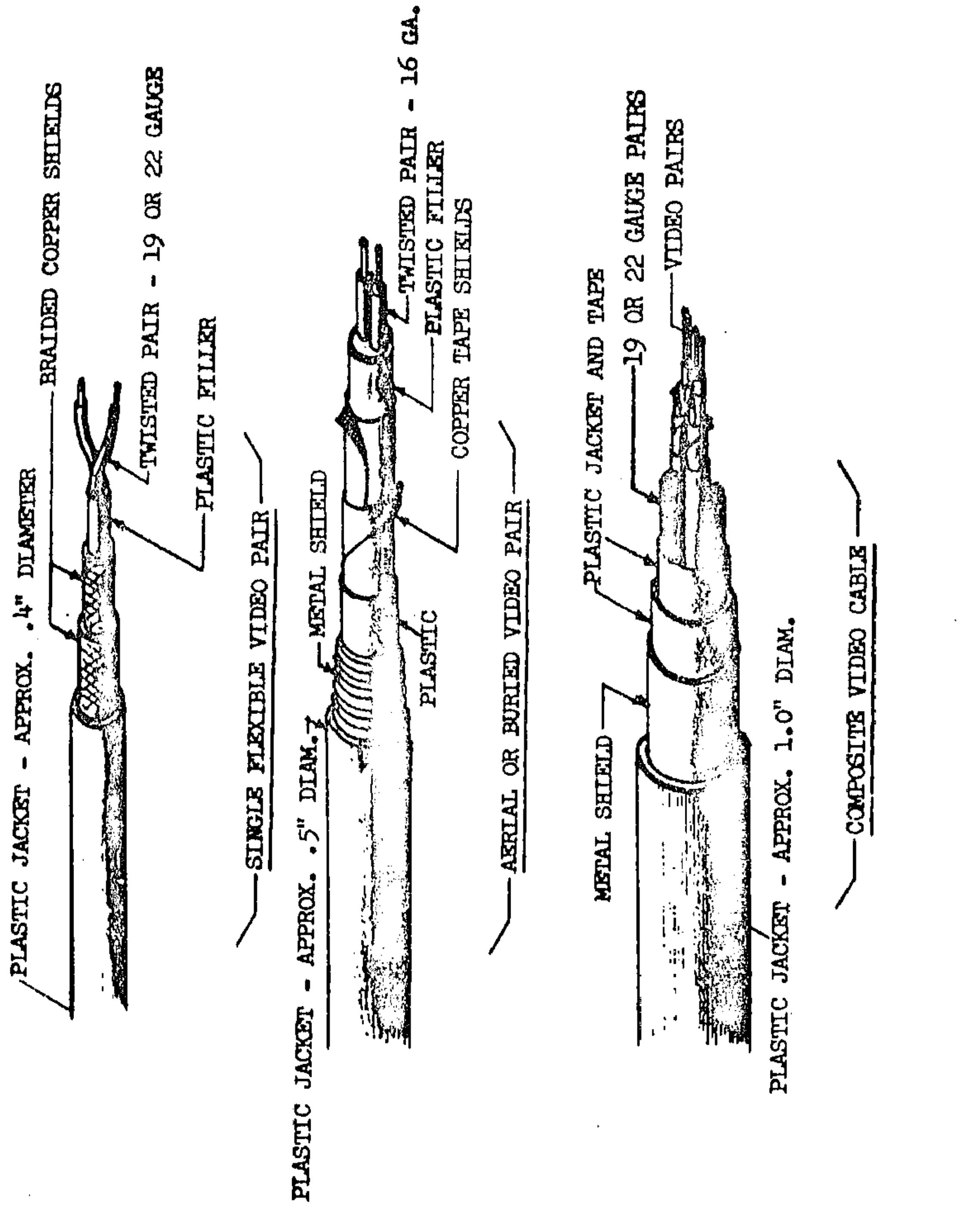
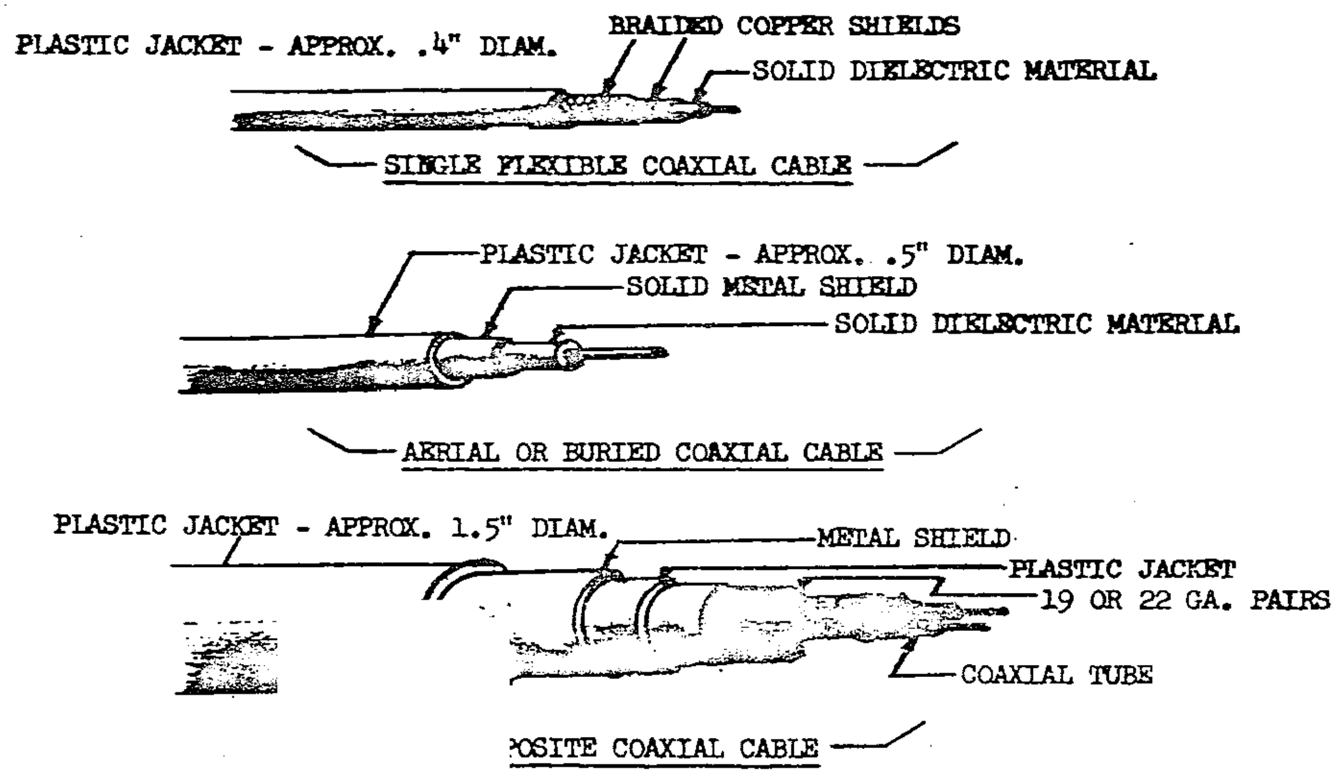

PLASTIC JACKET - APPROX. .4" DIAMETER
BRAIDED COPPER SHIELDS
TWISTED PAIR - 19 OR 22 GAUGE
PLASTIC FILLER
SINGLE FLEXIBLE VIDEO PAIR
PLASTIC JACKET - APPROX. .5" DIAM.
METAL SHIELD
TWISTED PAIR - 16 GA.
PLASTIC FILLER
COPPER TAPE SHIELDS
PLASTIC
AERIAL OR BURIED VIDEO PAIR
METAL SHIELD
PLASTIC JACKET AND TAPE
19 OR 22 GAUGE PAIRS
VIDEO PAIRS
PLASTIC JACKET - APPROX. 1.0" DIAM.
COMPOSITE VIDEO CABLE

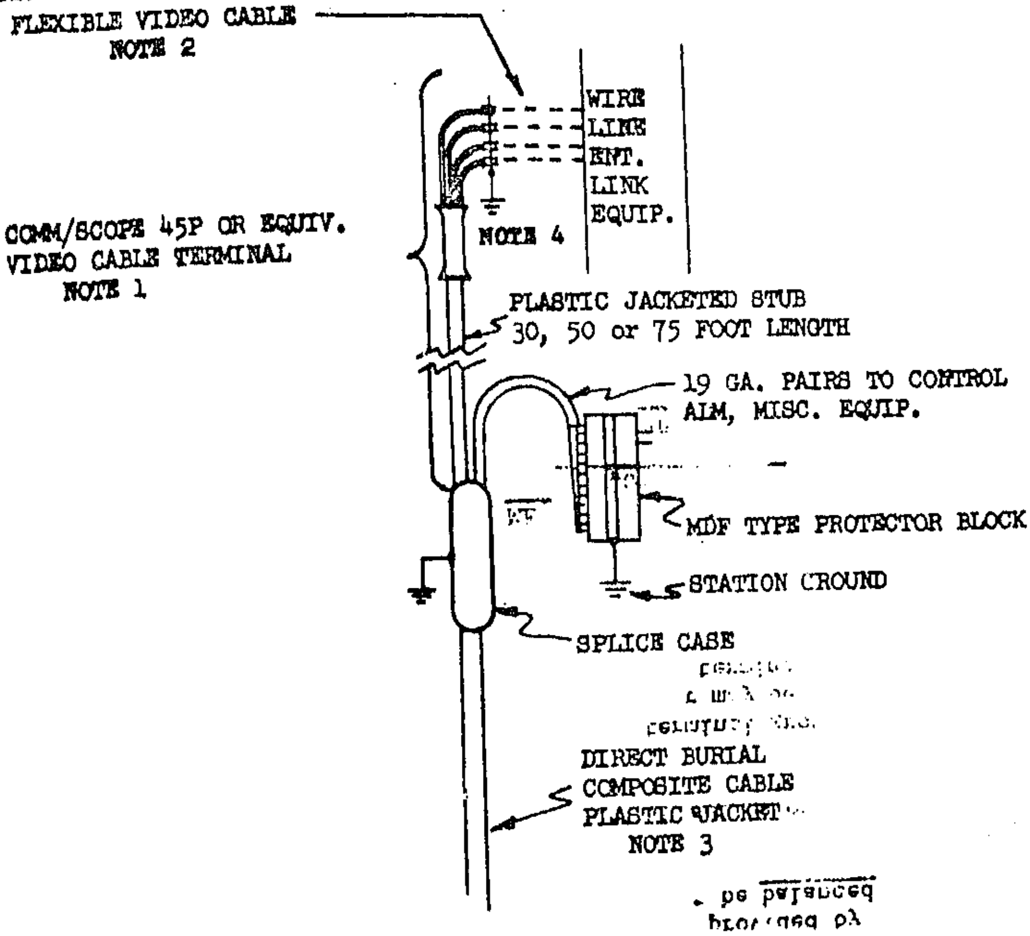
FIGURE 2



CAL VIDEO AND COAXIAL CABLES

FIGURE 2 CON'T

REA TE&CM 936



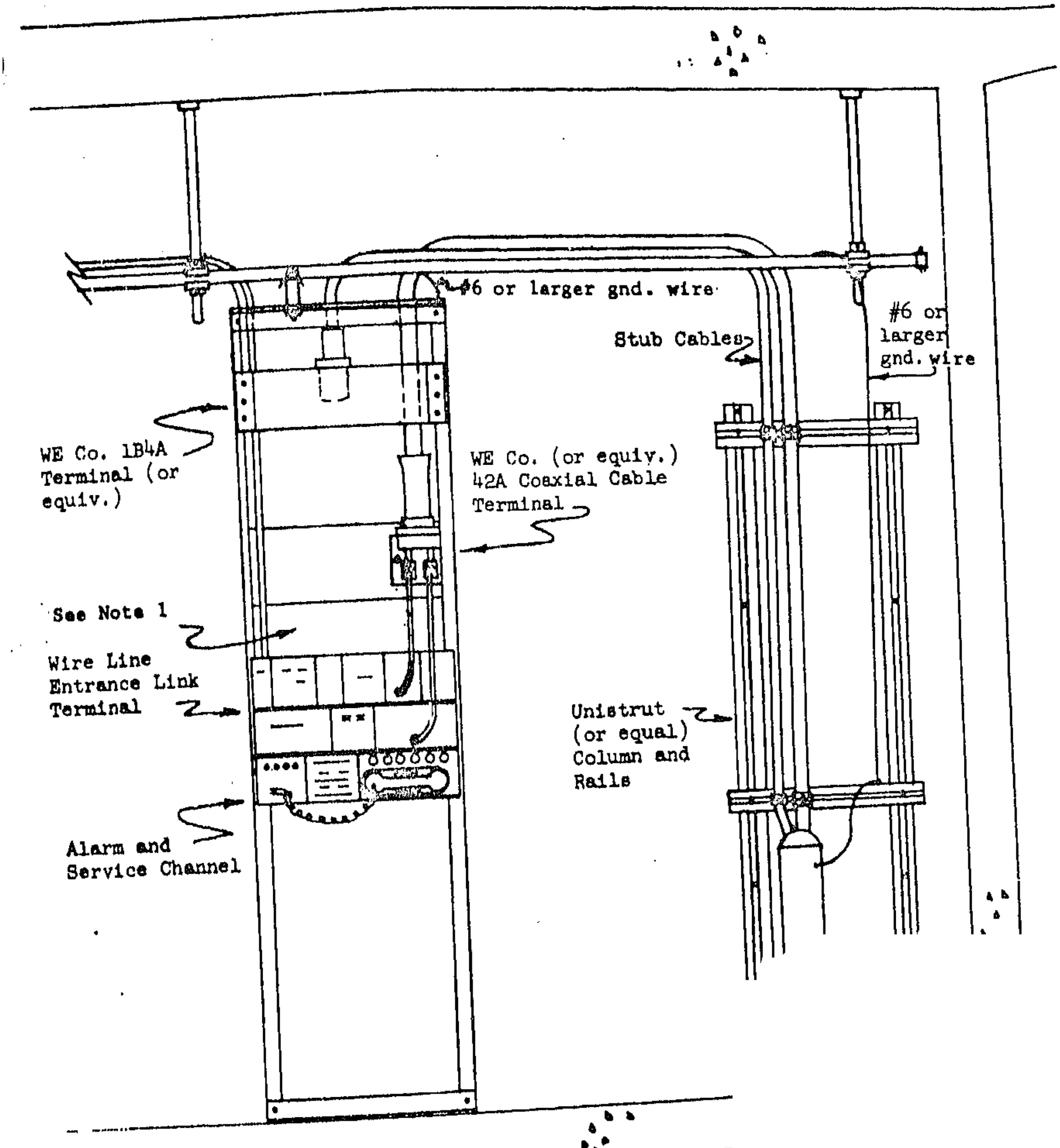
NOTES:

1. 45P provides termination of 4 video pairs in 4 type 8500 connectors. Mount at top of equipment rack.

2. Comm/Scope FVP 219 (or equiv.) flexible video cable terminated in a comm/scope (or equiv.) 6233 plug at 45P terminal. Other end terminated in wire line entrance link equipment shelf as provided by equipment manufacturer. Termination at equipment must be balanced 124 ohms.

3. Direct burial cable similar to General Cable Co. "V" series or comm/scope "VP" series. Control pairs optional.

4. Video pair shield is not connected to video c
Mounting screw insulators on each
removed to connect the video pai
ground.

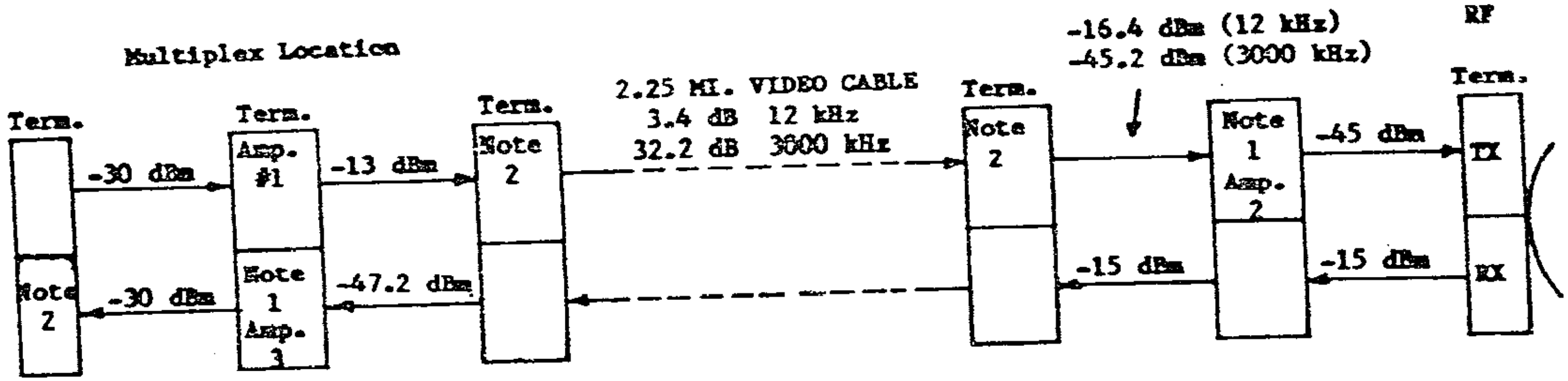


Note 1: Applications requiring lightning protection may u… Cardion E356 gas tube protectors (or equiv.) mounted on … suitable 19" panel adjacent to the coaxial cable termina…

SUGGESTED
COMPOSITE COAXIAL CABLE
TERMINATING PLAN

FIGURE 4

WIRE LINE ENTRANCE LINK



Note 1 Contains equalizer, amplifier and regulator

Note 2 Physical termination of outside plant

1. 16 gauge PSV video cable loss at 12 kHz. 1.5 dB/mile 1.5 x 2.25 = 3.4 dB
2. 16 gauge PSV video cable loss at 3000 kHz. 14.32 dB/mile 14.32 x 2.25 = 32.2 dB
3. Slope between 12 and 3000 kHz is equal to.................................... 28.8 dB
4. Slope correction requires one 16 dB equalizer, one 8 dB equalizer, one 4 dB equalizer and one 1 dB equalizer. (16 + 8 + 4 + 1 = 29)
5. Insertion loss of equalizers is 3.3, 1.7, .9 and .2 dB for 16, 8, 4 and 1, respectively.
6. Equalization loss at 12 kHz is 16, 8, 4 and 1 dB for each type of equalizer.
7. Equalization loss at 3000 kHz is 0 dB for each type of equalizer.
8. Total losses at 12 kHz = line loss + equalizer losses = 3.4 + 16 + 8 + 4 + 1 + 3.3 + 1.7 + .9 + .2 = 38.5 dB

FIGURE 5

10. Amplifier has 40 dB gain. Minimum input level -54 dBm/channel. Maximum output -13 dBm/channel. With 600 channel loading noise performance is 18 dBrnc0.

11. Multiplex output -30 dBm/channel + (-38.5) dB line loss = -68.5 dBm which is below minimum amp. input. Requires two amps. Place one amp. each end to raise receive level.

12. Set gain of amp. #1 (multiplex end) for maximum output (-13 dBm). Assume no loss in flex. video cable between WLEL shelf and video terminating assembly. Flex. video cable loss is 4.9 dB/1000' at 4 MHz.

13. Receive level at amp. #2 will be -13 + (-38.4) = -51.4 dBm flat (± .1 dB).

14. Set gain of amp. #2 for -45 dBm output to radio transmitter.

15. Radio output -15 dBm/channel + (-38.5) dB line loss = -53.5 dBm input to amp. #3 after equalizer.

16. Set gain of amp. #3 for -30 dBm/channel to multiplex input.

17. Near end crosstalk (NEXT) calculation assumes 110 dB coupling loss between video pairs.

18. NEXT multiplex end -13 + (-110) -53.5 = 69.5 S/N. 88.5 - 69.5 = 19 dBrnc0. Say OK.

19. NEXT radio end -15 + (-110) - 51.4 = 73.6 S/N. 88.5 - 73.6 = 14.9 dBrnc0. Say OK.

20. Figure 8 shows 1.5 dB/mile change at 3000 kHz when temperature changes +20° to +100°F.

21. Total level change = 1.5 x 2.25 = 3.37 dB. Add regulation.

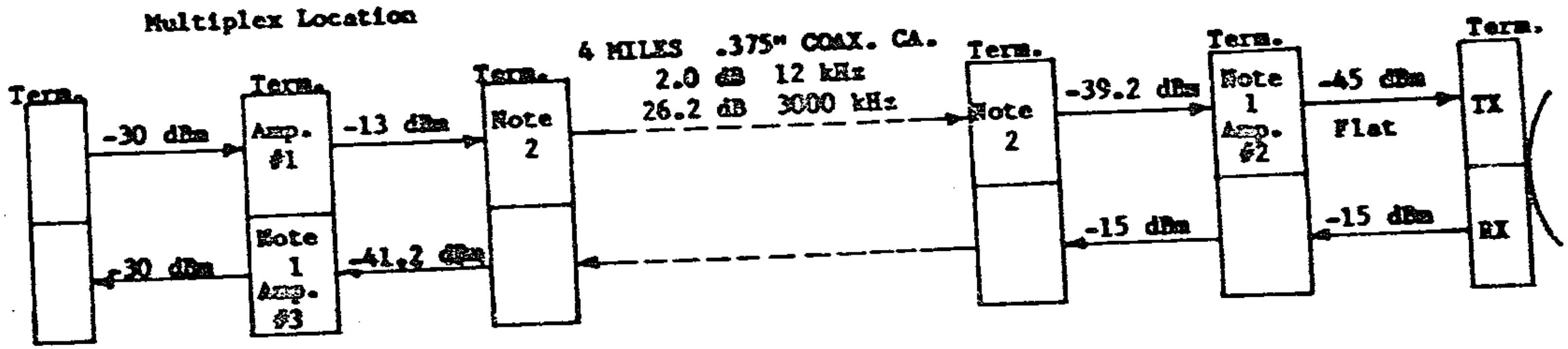
2.25 MILE
WLEL USING VIDEO PAIRS

FIGURE 5

CONTINUED

WIRE LINE ENTRANCE LINK

RF Location

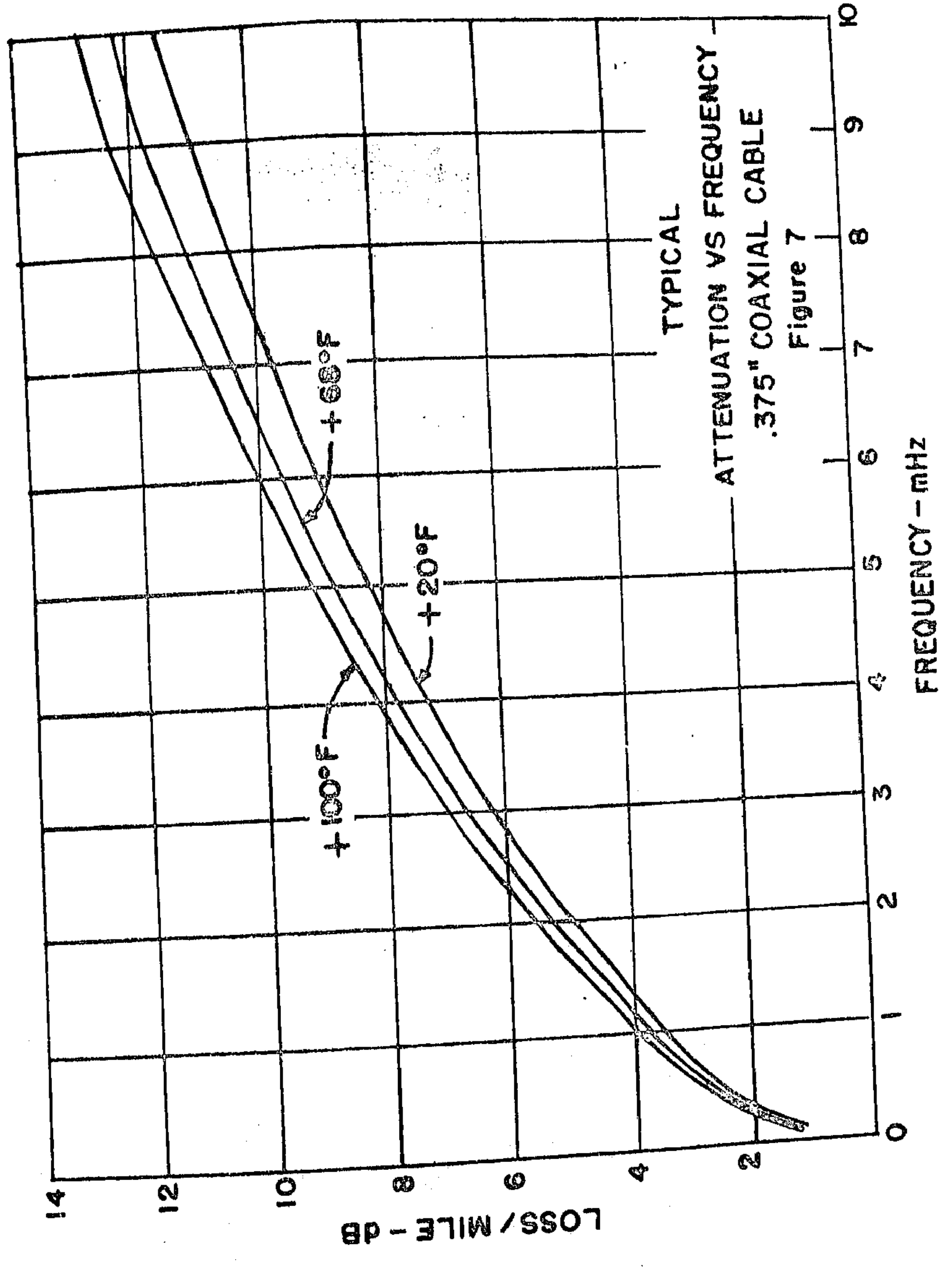


Note 1 Contains equalizer, amplifier and regulator

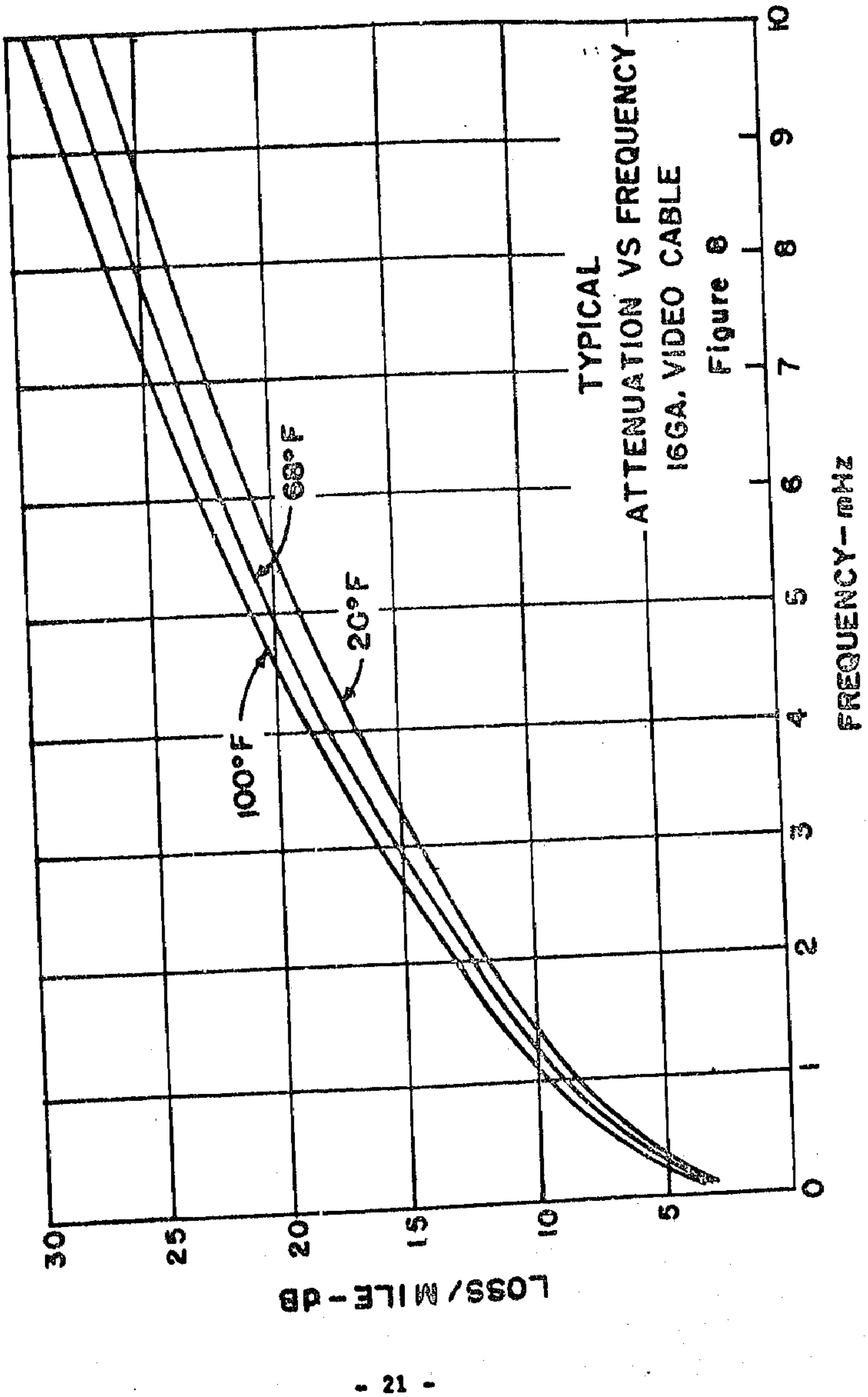
Note 2 Physical termination of outside plant

1. .375" coaxi :able loss at 12 kHz is .5 dB/mile. .5 x 4 = 2.0 dB
2. .375" coaxi : loss at 3000 kHz is 6.55 dB/mile. 6.55 x 4 = 26.2 dB
3. Slope betw id 3000 kHz is equal to 24.2 dB (26.2 - 2.0 = 24.2).
4. Slope corr equires one 16 dB equalizer and one 8 dB equalizer.
5. Insertion equalizers is 3.3 and 1.7 dB, respectively.
6. Equalizati at 12 kHz is 16 dB and 8 dB for each type of equalizer.
7. Equalizat: 3000 kHz is 0 dB for each type of equalizer.
8. Total los z = line losses + equalizer losses = 2 + 16 + 8 + 3.3 + 1.7 = 31.0 dB
9. Total los kHz = line losses + equalizer losses = 26.2 + 3.3 + 1.7 = 31.2 dB

FIGURE 6



TYPICAL
ATTENUATION VS FREQUENCY
.375" COAXIAL CABLE
Figure 7



TYPICAL
ATTENUATION VS FREQUENCY
166A VIDEO CABLE
Figure 8